COMPUTATIONAL METHODS FOR MULTI-SCALE, MULTI-UNCERTAINTY AND MULTI-PHYSICS PROBLEMS

Evolution and Propagation of Pre-existing Crack in the Core of an Earth- Rockfill Dam Due to Reservoir Impoundment

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Cracks in the core of earth-rockfill dams can be induced by many factors, such as temperature variations, soil shrinkage or settling of foundations. Following a change in stress state, the generated cracks can propagate through the core of the dam, thereby endangering its safety and long-term performance. An impoundment of an upstream reservoir can lead to a recognizable increase in hydraulic pressure on the inner faces of initially existing cracks, which eventually triggers the propagation of cracks through the core of the dam. This phenomenon is termed as 'Hydraulic fracturing'. Since the failure of Teton dam in 1976, the occurrence of hydraulic fracturing in the soil core of earth-rock fill dams is considered an important geotechnical problem relating to the safety of such dams.

In this work, hydraulic fracturing in the core of an earth-rockfill dam due to impoundment of reservoir is studied within the framework of eXtended Finite Element Method (XFEM), while employing a traction-separation cohesive behavior in Abaqus/Standard. The propagation of a crack, pre-existing at the upstream face of the core, is investigated. In this context, the water wedging action within the crack is also considered by considering tangential and normal flow within and across the crack.

This study successfully elucidates that after the reservoir is impounded, an initial crack present in the core of the dam propagates further only when a leak-off coefficient is considered, which allows to simulate the normal flow of fluid across the crack. This observation re-enacted the hypothesis that pre-existing cracks in the core of zoned dams are able to grow further upon the action of fluid pressure on the crack surfaces. In this regard, a sensitivity study is conducted to arrive at a suitable value of the leak-off coefficient for the dam. It is envisaged that hydraulic fracturing, leading to the further crack propagation, occurs in the adjacent element just beyond the crack tip when the normal stress perpendicular to the crack plane gets transformed from its compressive state to the tensile state. This study shows that an initial crack present on the upstream face of the core above a height of 50 m from the base (specifically for the dam section chosen in the present study) is likely to propagate further due to water wedging action and pressure generated due to the reservoir impoundment. However, it is observed that initial cracks at any other elevation below the ascertained height (from the base of dam) does not induce further crack propagation. This is attributed to the fact that the compressive stresses due to gravity load of the dam material at larger depths are sufficiently higher. In such scenario, the

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water pressure acting on the crack surface might not be enough to lower the effective stresses to a tensile state. Owing to larger depths from the impounding water level, the reservoir water would also take longer time to seep into those depths since they are comparatively far from the dam upstream face. The study successfully highlights that the upper part of the dam core is more prone to severe crack formations and progressive crack propagation to deeper lengths due to reservoir filling.

Keywords: Earth-rock fill dams; Reservoir Impoundment; Hydraulic Fracturing; XFEM; Water wedging action; Crack propagation.